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Final report of the „Synthesis of new *C*-glycosylated *O*-heterocycles with linkers of various lengths" project

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The importance of O-heterocycles produced by Nature such as flavones and chromones is well known. These compounds often contain a carbohydrate moiety in different position on the skeleton as *O*- or *C*-glycosyl flavonoids. These molecules possess wide and interesting biological activities. Especially, *C*-glycosyl flavonoids show a wide variety of bioactivities such as antiviral, cytotoxic, anti-inflammatory and DNA binding activities.

In case of the *C*-glycosyl flavonoids the anomeric carbon of the carbohydrate is directly connected to the aromatic ring. However, *no* precedents were found for compounds which have different connection point on the carbohydrate ring or any spacer between the sugar moiety and the aromatic *O*-heterocycle part. It means there is not any result for the biological activities of such compounds; therefore our aim was to prepare such structurally novel *O*-heterocycle-sugar compounds.

Another important fact is dietary flavonoids show low bioavailability which can be improved by structural modification, e.g. methylation. *O*-Glycosylated flavonoids were shown to undergo a quick deglycosylation in cells; consequently the incorporation of a non-cleavable *C*-glycoside unit to the flavone skeleton may alter both metabolism and adsorption pathways. Due to the lack of any *C*-glycosyl flavonoids, -chromanoids having linker between the flavonoid and sugar moiety our target compounds represent structures of high biological interest.

In the frame of this project we have successfully prepared, characterized a series of structurally novel *O*-heterocycle—carbohydrate derivatives with diverse structures.

We wished to investigate the scopes and limits of modern palladium catalyzed cross-coupling reaction in the synthesis of *O*-heterocycles with sugar moieties. Mostly, we focused on the Mizoroki-Heck reactions of the haloflavones and -chromones and their saturated variants with different pentose and hexose derivatives having alkenyl side-chain resulting in an unsaturated linker between the *O*-heterocycle and sugar moiety. Since our results are partially published, exact reaction conditions are not indicated in all case.

1. Palladium catalyzed cross-coupling reactions of 'allyl-sugars' with *O*-heterocycles

First, we focused on the cross-coupling reactions of 6- and 7-bromoflavones (**1a,b**) with β-D-ribofuranose derivatives **2a,b** to build up an unsaturated linker between flavone and sugar moiety. The syntheses of β-D-ribofuranose **2a,b** was carried out by Vogel's group at University of Rostock. The cross-coupling reaction of 7-bromoflavone (**1a**) with 1-allyl-β-D-ribofuranose derivative **2a** was performed under classical Heck-Mizoroki condition (**3a**: 63%) and with the phosphine-free Jeffery's methods (**3a**: 89%). Henceforth the phosphine-free conditions were applied, because the yield of this method was higher. The cross-coupling reactions of 1-allyl-β-D-ribofuranose (**2a**) and 1-allyl-2-desoxy-β-D-ribofuranose (**2b**) revealed derivative **2a** results the products in higher yields in all cases.

1a-e

1	position	R^2
a	7	Ph
b	6	Ph
c	7	H
d	6	H
e	8	Ph
f	8	H

2a,b

1a: R^1 = OBn

1b: R^1 = H

3a-l

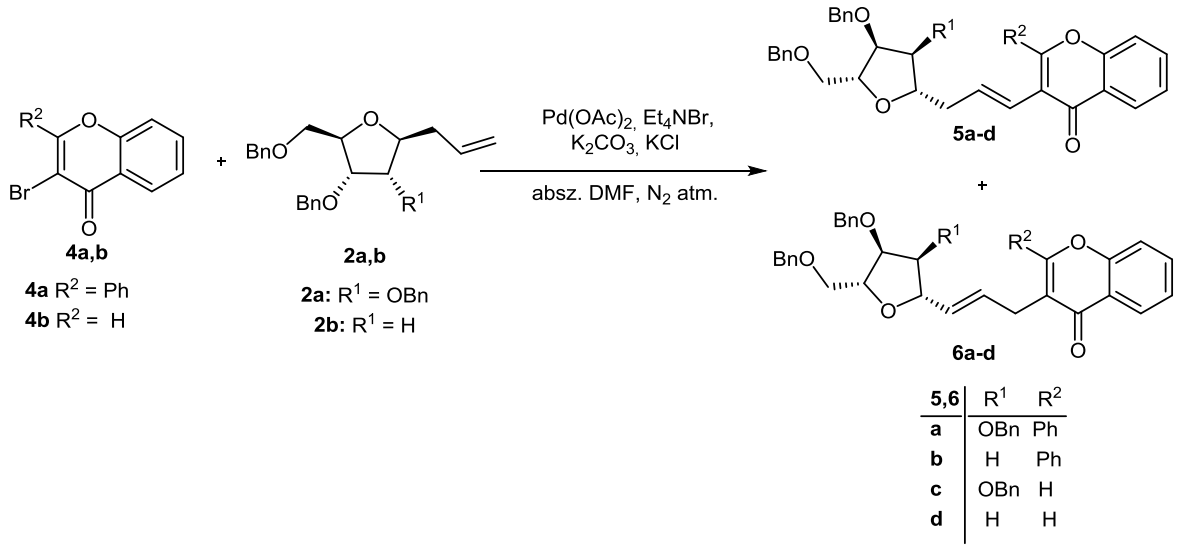
3	position	R^1	R^2
a	7	OBn	Ph
b	7	H	Ph
c	7	OBn	H
d	7	H	H
e	6	OBn	Ph
f	6	H	Ph
g	6	OBn	H
h	6	H	H
i	8	OBn	Ph
j	8	H	Ph
k	8	OBn	H
l	8	H	H

Scheme 1

In case of 7-bromoflavone (**1a**) the corresponding products were isolated in 89% (**3a**) and 68% (**3b**) yields, respectively. In case of 6-bromoflavone (**1b**) the corresponding products were isolated in 92% (**3e**) and 75% (**3f**) yields. By comparing the yields of the cross-coupling reactions of 1-allyl-β-D-ribofuranose (**2a**) and 1-allyl-2-desoxy-β-D-ribofuranose (**2b**) derivatives, revealed furanose **2a** provides the products in higher yields in all case. This result could be explained by the easier coordination of palladium in the presents of OBn group in position 2 as an oxygen donor group. Furthermore, by reviewing the literature of the biological activities of *C*-glycosyl flavonoids, we realized 8-*C*-glycosyl flavonoinds showed the most versatile and valuable effects. Consequently, we started to solve the problem of the synthesis of 8-bromoflavone (**8e**). Although, the 8-bromoflavone (**8e**) is a known

compound, its synthesis has not been described in the literature. The key step was the optimization of the synthesis of 3'-bromo-2'-hydroxyacetophenone. This synthetic pathway was worked out and the detailed process for the synthesis of 8-bromoflavone (**8e**) was published in the journal Synthesis. The application of 8-bromoflavone (**8e**) in this kind of reactions was also successful (**3i**: 86%, **3j**: 54%).

The reaction of 7-bromochromone (**1c**) afforded the corresponding products in good yields (**3c**: 79%, **3d**: 49%) Whereas, the same reaction of 6-bromochromone (**1d**) resulted compounds **3g,h** in moderate yields (44%, 28%) (Scheme 1). This trend in the reactivity of regioisomers of bromoflavones and -chromones is in agreement with our earlier observation. Namely, in the presence of an electron donating group at *para* position of aryl bromide such as flavones and chromones, their reactivity is reduced in the Heck-Mizoroki reaction. The reaction of 8-bromochromone (**1f**) afforded the corresponding products in good yields (**3k**: 62%, **3l**: 32%)

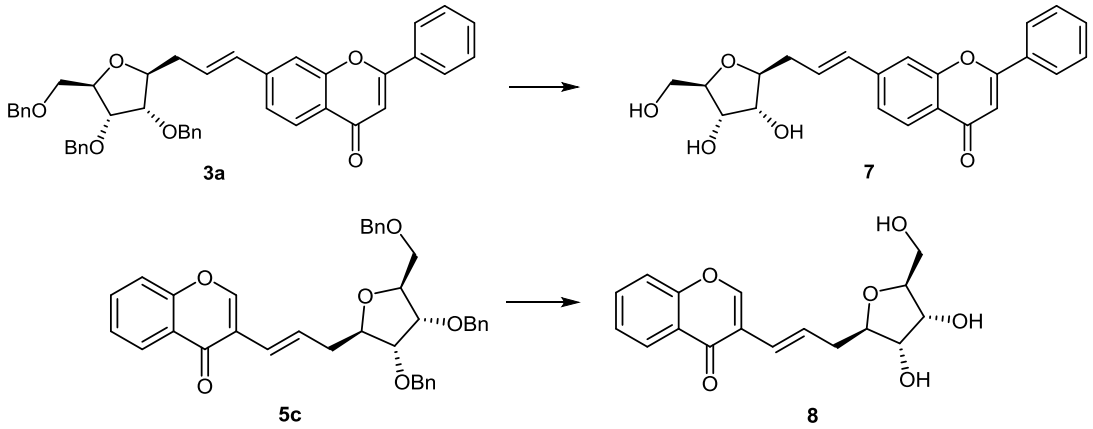


5,6	R^1	R^2
a	OBn	Ph
b	H	Ph
c	OBn	H
d	H	H

Scheme 2

An extension of this approach was the synthesis of flavones with a furanose unit at position 3 with utilizing 3-bromoflavone (**4a**). The transformation of **4a** to flavone-ribofuranose compounds **5a** and **5b** was managed to carry out under the same condition as in case of **1a-d**, however two products (**6a:** 21% and **5a:** 20%; **6b:** 18% and **5b:** 18%) were formed in these reaction. The palladium catalyzed cross-coupling reaction of chromone **4b** and **2a** gave similar results (**6c**: 18%, **5c**: 50%). The separation of the formed compounds was successful

and the structure elucidation was supported by 2D NMR measurements. In the case of flavone **4a** revealed isomer **5a** and **6a** were formed approximately in 1:1 ratio due to the migration of the double bond (Scheme 2). This isomerism occurred also in case of 3-bromochromone (**4b**) with terminal alkene **2a** during the cross-coupling reaction and isomer **5c** and **6c** were formed in ~ 3:1 ratio (**5c**: 50%, **6c**: 18% yield, respectively) (Scheme 2). This type of phenomena can be explained by literature similarity as in case of other allyl derivatives in the presence of palladium. We realized that the reaction time can be reduced since the reaction was complete in 1.5 hour in the case of the reaction of 3-bromochromone (**5b**) and terminal alkene **2a** (**6d**: 24%, **5d**: 39%). By comparing the isomer ratios of flavones and chromones, it is obvious that isomerism is occurred more readily in case of chromones.



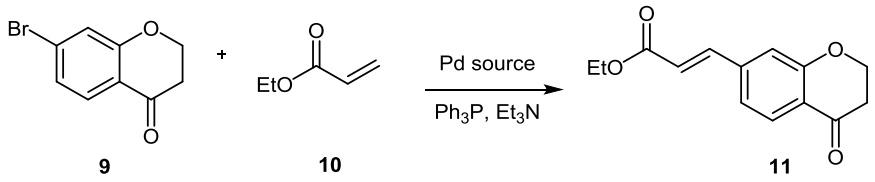
Scheme 3

Next, the debenzylation of flavone **3a** and chromone **5c** derivatives were achieved by treatment with $BCl_3.Me_2S$ complex in CH_2Cl_2 in 60% yield. This protocol was used in order to preserve the unsaturated linker; this would not be possible by means of catalytic hydrogenation. The detailed research results were published as a paper in Synlett.

Investigation of the Heck-Mizoroki reactions of chromanones

In order to wider the range of the applied oxygen heterocycles with further compounds such as flavanones or chromanones; these derivatives were also considered as substrates. However, their use in Heck-Mizoroki reaction has not been tested so far at all. Our first attempt to carry out this reaction with **2a** under the earlier successfully applied Jeffery's condition is failed. Since the Heck-Mizoroki reaction of the halochromanone derivatives in

the literature is not known, we began the investigation of the Heck-Mizoroki reaction of 7-bromochromanone (**9**) and ethyl acrylate (**10**) (Scheme 4).



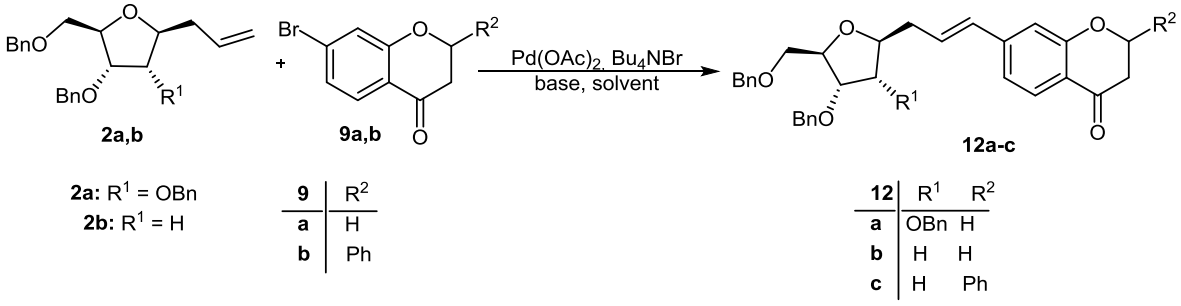
Scheme 4

Our study was started by utilizing $Pd(0)(PPh_3)_4$ as catalyst in NMP but no transformation was found. We changed the solvent to THF but a complex reaction mixture was formed after one day heating. The application of $Pd(OAc)_2$ provided the corresponding compound **11** in low yield (5%) after a long reaction time. However, no starting material was found in the reaction mixture, presumably it was decomposed due to the base sensitivity of chromanones.

In order to reduce the chance of the decomposition of the chromanone unit, the reaction was carried out in shorter reaction time and with lower equivalent of triethyl amine (TEA). This modification was not enough, since the yield was similar. Therefore, the reaction time was reduced to 3 hours when the corresponding product was isolated in 23% yield. Furthermore, we tried to improve the yield by the increase of the amount of ethyl acrylate but this modification did not lead us to better yields.

Considering the fact that in case of bromoflavones the phosphine-free conditions were successfully applied, it seemed to a logical step to continue the study of the cross-coupling reactions of chromanones under Jeffery's condition. In spite of this method was well performing in case of flavones, only the decomposition of the chromanone **9** was observed. The next stage of the optimization involved the changing the base and the palladium source. In the base screen, only HCOONa yielded the desired product in satisfactory yield, whereas K_2CO_3, K_2CO_3 combined with NaOAc or HCOONa, K_3PO_4 were ineffective. If K_2CO_3 was alone added the starting material was decomposed, however the application of NaOAc or HCOONa with K_2CO_3 prevented the decomposition of the chromanone. Interestingly, if no base was used the reaction afforded the product in 14% yield. Better yields were achieved in the presence of HCOONa, and the increase of amount of the ethyl acrylate also improved the

yield up to 43%. We also investigated the reaction at lower and higher palladium catalyst loads. As it is known from the literature, in some cases the lower palladium catalyst loading can have advantageous effect on the yield in the cross-coupling reaction. Therefore, the reaction was repeated with 1% $Pd(OAc)_2$ during extended reaction time, but the yield was decreased whereas unreacted starting material was present in the reaction mixture. Then, the optimization was performed with 10% $Pd(OAc)_2$, but similar observation was taken. As a result, in our case these modifications were not prosperous. Potassium chloride was utilized as an additive in these transformations and its positive effect is clear, since in those reactions when KCl was not added the yield of the product was low. In one case, $Pd(OTf)_2$ was used as palladium source, but significant development in the yield was not observed. DMF and THF were tested as solvent, both seems to be suitable for the Mizoroki-Heck reaction of compounds 7-bromochromanone (**9**).



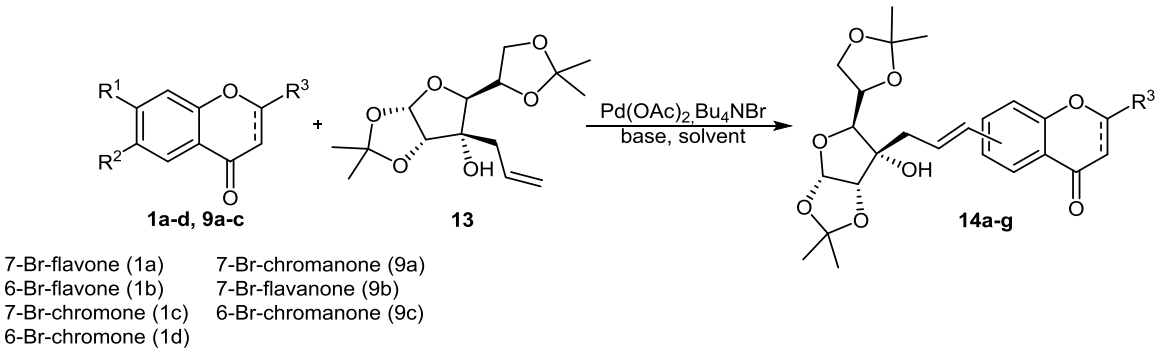
2a: R^1 = OBn
2b: R^1 = H

9	R^2
a	H
b	Ph

12	R^1	R^2
a	OBn	H
b	H	H
c	H	Ph

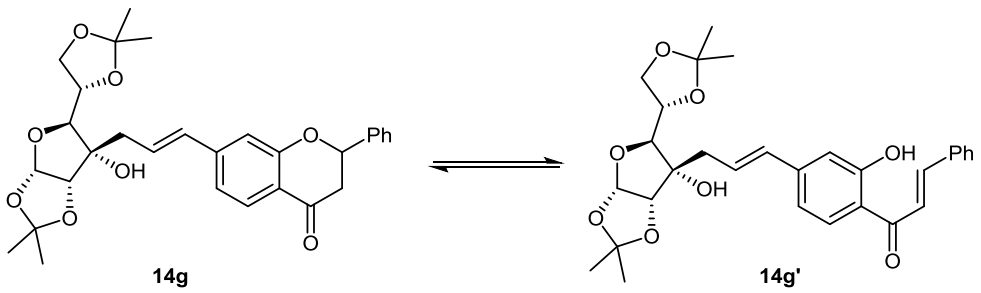
Scheme 5

The study of the synthesis of chromanone(flavanone)-carbohydrate compounds was achieved with compound **9a,b** with 1-allyl-riboses **2a** and **2b** under phosphine-free Jeffery's condition. The Jeffery's condition with K_2CO_3, which worked well in case of flavones and chromones, gave a complex reaction mixture. However, the newly developed Jeffery's method using HCOONa as base successfully provided the unique chromanone/flavanone-ribofuranose compounds **12a, 12b** and **12d** in low yields (18%, 14%, 11%, respectively). The classical Heck condition afforded compound **12a** in higher yield (34%), but the prolongation of the reaction time was disadvantageous.



Scheme 6

In order to expand the range of allyl sugars a protected 3-hydroxy-3-allylfuranose **13** was prepared starting from 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose, which compound was oxidized by Swern oxidation to afford the 1,2:5,6-di-O-isopropylidene-α-D-ribo-hexulofuranos-3-ulose. The desired compound **13** was obtained by utilizing allylmagnesium bromide *via* Grignard reaction. Then 3-hydroxy-3-allylfuranose **13** was tested under the same reaction condition as derivatives **1a,b**. Bromoflavone **1a,b** yielded the corresponding compounds in good yield (80%) within short reaction time (3 h). Bromochromones **3c,d** gave the compounds in lower yields (up to 37%) during the time of full conversion (3 h). The base sensitivity of 2,3-dihydro-4H-pyran-4-one was more obvious in the case of bromochromanones **9a,c** since the yields were dropped (down to 16%) in spite of the short reaction time and full conversion, even in these reactions HCOONa was used. In the case of the 7-bromoflavanone (**9b**) the product was isolated as a tautomer mixture of the flavanone and chalcone (Scheme 7) in 18% yield.

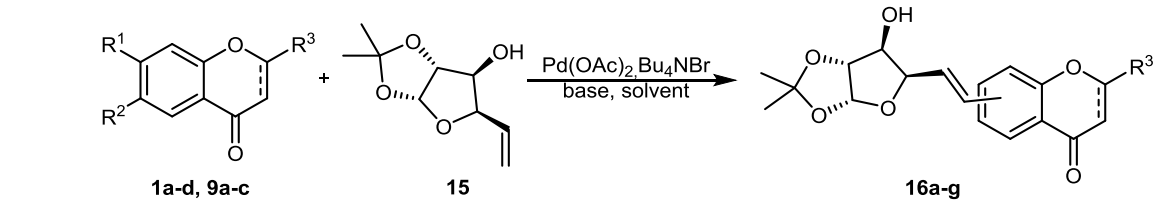


Scheme 7

In all cross-coupling reactions of the 'allyl-sugars' the formation of *trans* isomers were detected exclusively.

2. Palladium catalyzed cross-coupling reactions of 'vinyl-sugars' with *O*-heterocycles

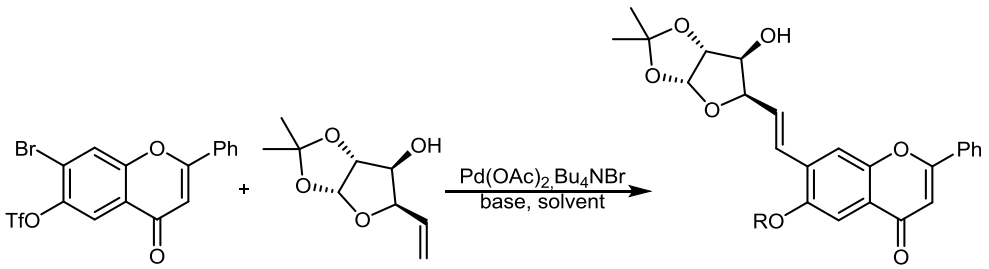
In the next stage of the project, we focused on the Heck-Mizoroki reactions of carbohydrates having vinyl group at different position on the furanose or pyranose ring. Therefore, the synthesis of 5,6-dideoxy-1,2-O-isopropylidene-α-D-xylo-hex-5-enofuranose (**15**) was performed and the substrate scope was further surveyed.



7-Br-flavone (1a) 7-Br-chromanone (9a)
6-Br-flavone (1b) 7-Br-flavanone (9b)
7-Br-chromone (1c) 6-Br-chromanone (9c)
6-Br-chromone (1d)

Scheme 8

The reactions of vinyl furanose **15** under the same condition as mention in the case of **3a-h**, provided the corresponding compound **16a,b** in 79% and 70% yield as *trans* isomers, respectively. The bromochromones **1c,d** showed identical stereoselectivity and the yields were comparable with bromoflavones (**16c**: 71%, **16d**: 72%). The chromanone derivatives and flavanone **9c** gave the products in low yields (10-30%). The reaction of vinyl furanose **15** with different oxygen containing heterocycles showed high *trans* stereoselectivity.



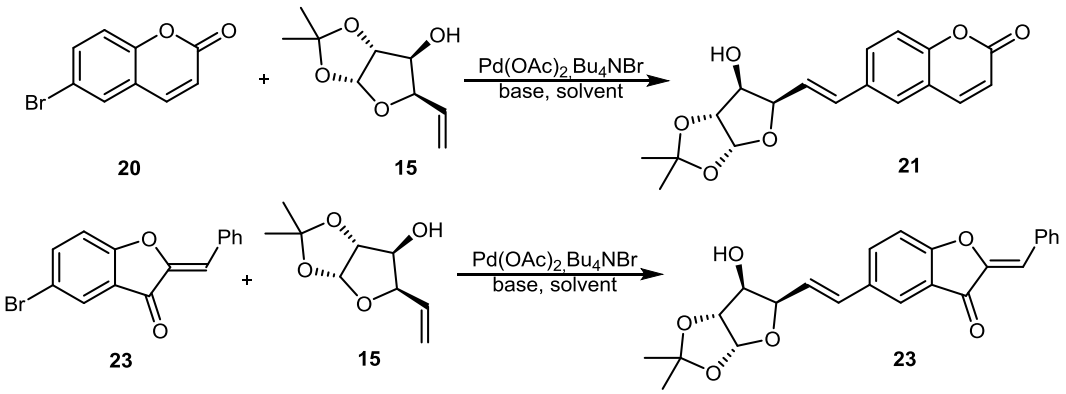
Scheme 9

In order to prepare a disubstituted compound, 7-bromo-6-triflyloxyflavone (**17a**) was involved in the study, since this compound has two substituents which can take part in the cross-coupling reaction. The application of a pseudo halide (OTf) is known in the literature, in different palladium catalyzed reactions. Thus, we envisioned that these transformations

could be selectively controlled at various stages to afford the desired products by tuning the reaction parameters. The reaction proceeded smoothly (**19b**: 44%), although the hydrolysis of the OTf group was observed. In order to investigate whether the hydrolysis or the cross-coupling reaction occurred first, the reaction of 7-bromo-6-hydroxyflavone (**17b**) was carried out, but no transformation was occurred (Scheme 9). It means, the cross-coupling reaction was successful, and then the formed product **19a** was hydrolyzed.

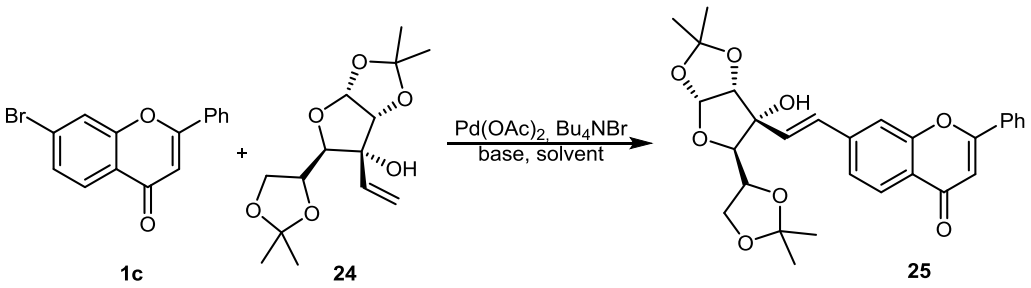
Parallel, we started the synthesis of the bis(triflate) of 1,4-dihydroxy-9H-fluoren-9-one in order to involve this compound into the range of the studied substrates. However, the utilization of 9H-fluoren-9-one derivative is postponed, because of the above mentioned hydrolyzation side reaction. Nevertheless, this bis(triflate) was used in other cross-coupling reaction and the results were summarized in an article and published in Synlett.

In order to further broaden the scope of this reaction with respect to the *O*-heterocycle components, we employed a bromocoumarin **20** as well as –aurone **23** in this process, both of which delivered the desired products in good yields (**21**: 86%, **23**: 47%) (Scheme 10).



Scheme 10

The synthesis of new 'vinyl-sugar' **24** was achieved from 1,2:5,6-di-O-isopropylidene-α-D-ribo-hexulofuranos-3-ulose with vinylmagnesium bromide *via* Grignard reaction, however this reaction afforded the product **24** in low yield.

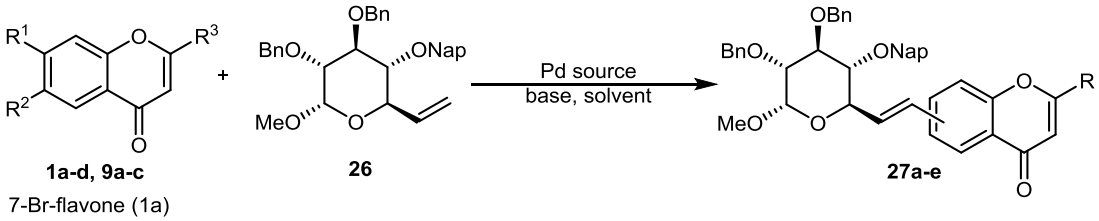


Scheme 11

Therefore, only one cross-coupling reaction was performed with 3-*C*-ethenyl-1,2:5,6-bis-O-(1-methylethylidene)-α-D-allofuranose (**24**), giving the desired product in good yield (56%) (Scheme 11).

The applied conditions did not cause the cleavage of the acetal protecting groups.

After these promising results regarding to the furanose compounds, we began the investigation of the 'vinyl-pyranose' derivatives in palladium catalyzed reactions.

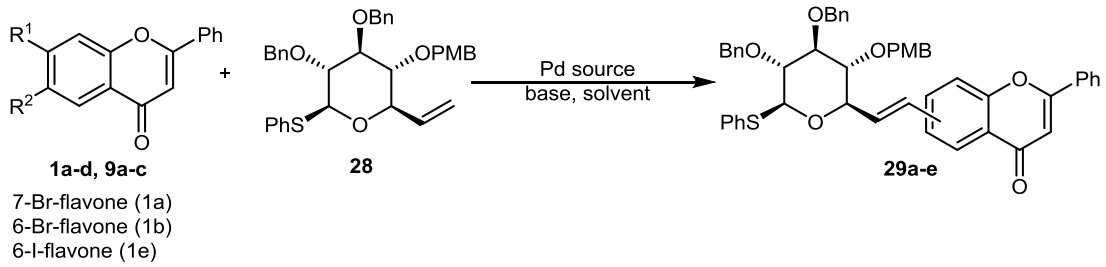


Scheme 12

Palladium-catalyzed Heck reaction of **1a** and methyl 6,7-dideoxy-4-*O*-(2-naphthalenylmethyl)-2,3-bis-*O*-(phenylmethyl)-α-D-*gluco*-hept-6-enopyranoside (**26**) using $Pd(OAc)_2/Ph_3P$ as catalyst-ligand pair was used to afford the desired product. Under these classical Heck condition the corresponding product was isolated in 49% yield. The previously successfully used phosphine free Jeffery's condition ($Pd(OAc)_2$, HCOONa, TBAB, KCl) resulted the same product in 30% yield. It is known from the literature, the application of silver(I) salts can increase the efficiency of the cross-coupling reactions. Therefore, 10% $AgNO_3$ was applied as an additive in the reaction and the yield was doubled (59%). If we used K_2CO_3 as base the yield was increased up to 84%. In case of **1b** the coupled derivative was isolated in

86% yield. It is well known iodo compounds can react more readily than bromo one. Whereas, we carried out the reaction of 6-iodoflavone (**1e**) and using even a weaker base (HCOONa) the product was isolated in good yield (74%) due to the increased reactivity of the starting material. The phosphine-free condition with K_2CO_3 worked well in case of bromochromones **1c**,**d** and the transformation successfully afforded the chromone-glucopyranoside derivatives **27c**,**d** (50%; 49% respectively). The applied conditions were suitable to keep the ether type protecting groups (Scheme 12).

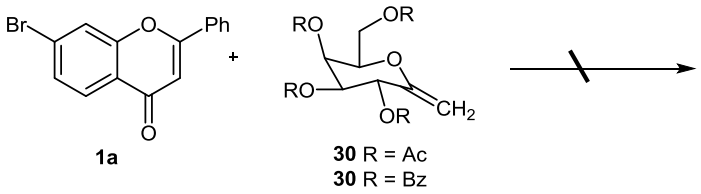
In the survey another pyranoside type compound was tested, namely the 6,7-dideoxy-4-*O*-[(4-methoxyphenyl)methyl]-2,3-bis-*O*-(phenylmethyl)-1-phenylthio-β-D-gluco-hept-6-enopyranoside (**28**).



Scheme 13

This compound was available in limited amount, because of this reason it was allowed to react only with haloflavones. 7- and 6-bromoflavone and 6-iodoflavone was used, using the phosphine-free Jeffery condition (K_2CO_3, $AgNO_3$) the product **29a-e** were obtained 70-88% yields (Scheme 13).

3. Palladium catalyzed cross-coupling reactions of 'methylidene-sugars' with *O*-heterocycles

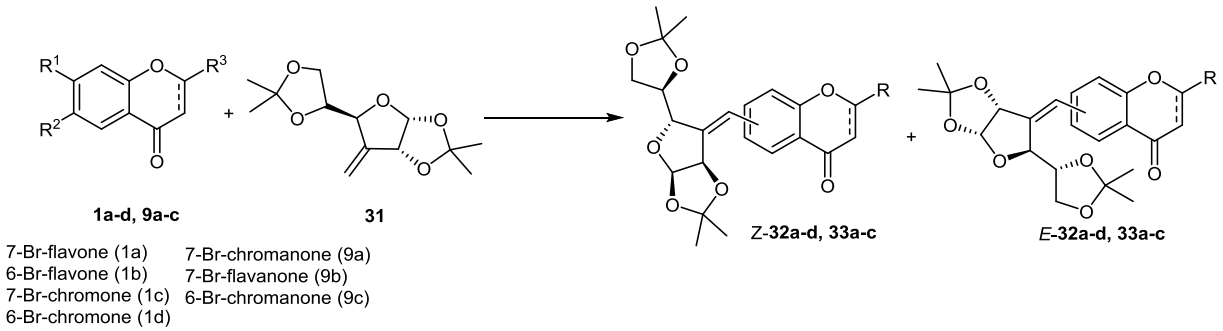


Scheme 14

The investigation of the cross coupling reactions of 7-bromoflavones (**1a**) and carbohydrates was extended to *O*-peracetyl (**30a**) and *O*-perbenzoyl (**30b**) *exo*-glycals of the D-*gluco* and D-*galacto* configurations. Due to the heat sensitivity of these carbohydrate derivatives the reactions were carried out at 100°C under argon atmosphere. As catalyst $Pd(OAc)_2$ or $Pd_2(dba)_3$ were added in 5-10% both under Heck and Jeffery's conditions. In the case of classical Heck conditions different phosphine ligands (e. g. PPh_3, XPhos, PCy_3) were added to the reaction mixture in 10-20% ratio. The following bases were applied for the transformations: K_2CO_3, Cs_2CO_3, KOAc, HCOONa, Et_3N usually in 1-3 equiv amount. Aprotic polar solvents e. g. *N,N*-dimethylformamide, acetonitrile and ether type solvents e. g. 1,4-dioxane, tetrahydrofuran were also investigated in these reactions. Heating the reaction mixtures up to 6 hours the conversion of the *exo*-glycal was not detected, although in most cases the dehalogenation of 7-bromoflavone (**1a**) took place resulting in the formation of flavone. Thereby, indicating the occurrence of oxidative addition which is the first step of the catalytic circle. In case of the *O*-perbenzoylated *exo*-glucal (**30b**) the reaction temperature was elevated up to 140°C, but the formation of the desired coupled product was not detected and the unreacted sugar was still present in the mixture. The lack of the formation of the cross coupled compound might be explained by the diminished reactivity of the enol ether type double bond of *exo*-glycal **30a** and **30b** (Scheme 14).

To increase the variety of the carbohydrate compounds; 1,2:5,6-di-*O*-isopropylidene-3-methylene-α-D-allofuranose (**31**) was synthetized and then used in the further reactions. The preparation of this compound started from the 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose, which compound was oxidized by Swern oxidation to afford the 1,2:5,6-di-O-isopropylidene-α-D-ribo-hexulofuranos-3-ulose. The isolated product was converted into

1,2:5,6-di-*O*-isopropylidene-3-methylene-α-D-allofuranose (**31**) by the treatment of methyltriphenylphosphonium bromide.



Scheme 15

The modified Jeffery's conditions were tested with 7-bromo-, 6-bromo-, 3-bromoflavones as substrates. In the case of 7- and 6-bromo compounds not only the expected *trans* product Z-**32a-d** were formed, but the *cis* isomers (*E*-**32a-d**) were also isolated. The 2D NMR experiments of the separated compounds revealed that during the reaction *Z* and *E* isomers were formed approximately in 1:1 ratio (*Z*-**32a** = 33%, *E*-**32a** =30%) (Scheme 15). Similar observation was found in case of 6-bromoflavone (*Z*-**32b**= 37%, *E*-**32b** =37%). In the case of 3-bromoflavone only the *trans*-alkene was formed in 9.6%.

Then, the cross coupling reaction of bromochromones **1c,d** was performed using Jeffery's methods. The chromone derivatives also provided the *cis* and *trans* isomers in moderate yields (*Z*-***32c***= 14%, *E*-***32c***=15%; 6-bromochromone: *Z*-***32c*** = 27%, *E*-***32c*** =28%).

The reaction of 7-bromochromanone (**9a**) with the same carbohydrate derivative under Jeffery's conditions resulted in the desired coupled product **33a**, although the yield was low (14%) and only the *trans* isomer was formed. In order to get the compound in higher yield, the reaction was carried out under the classical Heck conditions. The yield was increased although both *cis* and *trans* isomers were formed in 1:1 ratio (*Z*-***33a:*** 14%, *E*-***33a:*** 15%) (Scheme 15).

Summary

In order to create unique compounds, which are new analogs of the naturally-occurring *C*-glycosyl flavonoids in good yields, we successfully performed the palladium catalyzed cross-coupling reactions of carbohydrates with alkenyl chain and different oxygen-heterocycles. In the frame of this project the Heck reaction of chromanones and flavanones were also investigated. We have found effective reaction conditions to transform these base sensitive compounds *via* Heck-Mizoroki reactions. In the case of isolated derivatives with allyl and vinyl linkers we found high stereoselectivity. The products with methylylidene group showed the formation of both isomers usually in 1:1 ratio. Some biological assays have been done but unfortunately the selected derivatives did not show any effects. However, these structurally novel derivatives with various alkenyl spacers are interesting for other type of biological tests and may provide new hits for pharmaceutical R&D by improving metabolism and adsorption properties compare to natural *C*-glysosyl flavonoids. By this modern cross-coupling reaction, we managed to prepare such derivatives which synthesis is currently not solved on other pathways.

Our results were presented in national and international conferences as lectures and poster presentations (8). The publication of the project has been started; two articles are already published in the journal Synlett. The remained results already have been prepared for publication. Two other papers were also published in connection with the synthesis of new *O*-heterocyclic substrates. The results of the Heck-Mizoroki reactions were a base for a diploma work (Kovács Emese) and a PhD thesis (Kondor Zoltán, his thesis is under construction).

Krisztina Kónya

Publications:

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2. Zoltán Kondor, Mihály Herczeg, Anikó Borbás, Tamás Patonay, Krisztina Kónya. Application of Carbohydrates with Methylene or Vinyl Groups in Heck–Mizoroki Cross-Coupling Reactions with O-Heterocycles. *Synlett*, **2016**, DOI: 10.1055/s-0036-1588591
3. Dávid Pajtás, Tamás Patonay, Krisztina Kónya. Synthesis of 8-Bromoflavone and its Buchwald-Hartwig Reaction with amines. DOI: 10.1055/s-0035-1560325, *Synthesis*, **2016**, *48(01)*, 97-102
4. Marcel Sonneck, David Kuhrt, Krisztina Kónya, Tamás Patonay, Alexander Villinger, Peter Langer. Regioselective Suzuki–Miyaura Cross-Coupling Reactions of the Bis(triflate) of 1,4-Dihydroxy-9H-fluoren-9-one. DOI: 10.1055/s-0035-1560211, *Synlett*, **2016**, *27(01)*, 75-79

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2. Zoltán Kondor, Krisztina Kónya, Dilver P. Fuentes, Christian Vogel, Tamás Patonay. SYNTHESIS OF NEW FURANOID-CHROMONOID AND -FLAVONOID HYBRIDS WITH HECK REACTION. 20th International Conference on Organic Synthesis,. 29 June-4 July, 2014., Budapest
3. Zoltán Kondor, Tamás Patonay, Krisztina Kónya. Synthesis of Flavonoid- and Chromonoid-Furanoside Hybrids by Phosphine Free Heck Reactions. Bioheterocycles 2015, XVI International Conference on Heterocycles in Bioorganic Chemistry, Metz, France - June 8-11, 2015
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Miscellaneous documents:

1. Kovács, Emese: Investigation of the Heck-reaction of iodo- and bromoflavone derivatives, BSc diploma work, 2012
2. Kondor, Zoltán (Consultant: Krisztina Kónya): Cross-coupling reactions of halogen substituted chromonoids and coumarines with alkenyl carbohydrates, PhD thesis, 2016 (under preparation)